AFRL-HE-BR-TR-2005-0085

Air Force Research Laboratory

TEAM COMMINUCATION AND PERFORMANCE DURING SUSTAINED WORKING CONDITIONS

Donald Harville
Nadia Lopez

HUMAN EFFECTIVENESS DIRECTORATE
BIOSCIENCES AND PROTECTION DIVISION
FATIGUE COUNTERMEASURES BRANCH
2485 GILLINGHAM DRIVE
BROOKS CITY-BASE TX 78235-5105

Linda Elliott

ARMY RESEARCH LABORATORY
USAIC-HRED FIELD ELEMENT
FT. BENNING, GA 31905-5400

Christopher Barnes

MICHIGAN STATE UNIVERSITY
GRAD SCHOOL OF MANAGEMENT
EAST LANSING, MI 48823

May 2005

NOTICES

This report is published in the interest of scientific and technical information exchange and does not constitute approval or disapproval of its ideas or findings.

Using Government drawings, specifications, or other data included in this document for any purpose other than Government-related procurement does not in any way obligate the US Government. The fact that the Government formulated or supplied the drawings, specifications, or other data, does not license the holder or any other person or corporation, or convey any rights or permission to manufacture, use, or sell any patented invention that may relate to them.

The Office of Public Affairs has reviewed this paper, and it is releasable to the National Technical Information Service, where it will be available to the general public, including foreign nationals.

This report has been reviewed and is approved for publication.

//SIGNED//
DONALD L. HARVILLE
Contract Monitor

//SIGNED//
F. WESLEY BAUMGARDNER, Ph.D.
Deputy, Biosciences and Protection Division

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*
May 2005

2. REPORT TYPE
Interim

3. DATES COVERED *(From - To)*
October 2002 - August 2003

4. TITLE AND SUBTITLE
Team communication and performance during sustained working conditions

5a. CONTRACT NUMBER
NA

5b. GRANT NUMBER
NA

5c. PROGRAM ELEMENT NUMBER
62202F

6. AUTHOR(S)
Harville, Donald L., Elliott, Linda R., Barnes, Christopher, & Lopez, Nadia

5d. PROJECT NUMBER
7757

5e. TASK NUMBER
P9

5f. WORK UNIT NUMBER
04

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Human Effectiveness Directorate
Biosciences and Protection Div
2485 Gillingham Dr.
Brooks City-Base, TX 78235

Army Research Lab
USAIC-HRED Field Element
Ft. Benning, GA 31905-5400

Michigan State University
Grad School of Management
East Lansing, MI 48823

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Human Effectiveness Directorate
Biosciences and Protection Division
Fatigue Countermeasures Branch
2485 Gillingham Dr.
Brooks City-Base, TX 78235-5105

10. SPONSOR/MONITOR'S ACRONYM(S)
AFRL/HE

11. SPONSORING/MONITORING AGENCY REPORT NUMBER
AFRL-HE-BR-TR-2005-0085

12. DISTRIBUTION AVAILABILITY STATEMENT
Approved for public release: Distribution is unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT
The effects of prolonged working conditions on individual performance are well documented. Additionally military field studies, sports teams, and field expeditions have been conducted in sustained context. However, there have been few controlled, experimental studies on the effects of fatigue on complex decision making or team performance. The authors initiated a program of research to systematically investigate effects of fatigue on measurable aspects of team communication, coordination, decision making, problem-solving, and performance. As fatigue increased, teams' performance decreased on both major outcomes measured, and 10 of the 12 types of verbal communication differed in the predicted direction.

15. SUBJECT TERMS
Team Communication, Team Performance, Decision Making, Sustained Operations, Command and Control

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	c. THIS PAGE	17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	27	Harville, Donald L.

19b. TELEPONE NUMBER (*Include area code*)
210-536-3844

THIS PAGE INTENTIONALLY LEFT BLANK

TABLE OF CONTENTS

FIGURES

TABLES

SUMMARY

The effects of prolonged working conditions on individual performance are well documented. Additionally military field studies, sports teams, and field expeditions have been conducted in sustained context. However, there have been few controlled, experimental studies on the effects of fatigue on complex decision making or team performance. The authors initiated a program of research to systematically investigate effects of fatigue on measurable aspects of team communication, coordination, decision making, problem-solving, and performance. As fatigue increased, teams' performance decreased on both major outcomes measured, and 10 of the 12 types of verbal communication differed in the predicted direction.

INTRODUCTION

United States Air Force (USAF) command and control (C2) warfighters face increasingly complex environments that represent elements of intense teamwork (Cohen, 1993; Klein, 1993; Orasanu & Salas, 1991; Rasmussen, 1993). In tactical C2 situations, the focus is on dynamic battle management and time-critical targeting. High-reconnaissance coordination demand and resource allocation depend upon close coordination between ground and air forces in a distributed network system of systems. Such situations require C2 operators to exercise close coordination and adaptive replanning, often in battlefield operations under conditions not conducive to good sleep. As a result, C2 operators often are chronically tired and sleep-deprived. Over time, this chronic fatigue affects everyone and the likelihood of error increases (Bonnet, 2000; Hursh, 1998). This is particularly relevant in C2 situations, which require constant monitoring even when events are still.

While interventions (e.g., caffeine, pharmaceuticals, and naps) for fatigue exist (Eddy & Hursh, 2000) and have proven to ameliorate affects, additional interventions (e.g., information display, monitoring, decision support, and alerting mechanisms) need to be developed. To facilitate their development, controlled studies are needed to determine what kinds of errors are made, by whom, and when. While extensive data are available on the effects of sleep loss on physiological, attitudinal, and cognitive functions (Kryger, Roth, & Dement, 2000), very few studies have reported data regarding sleep loss effects on particular aspects of information processing in complex team performance and decision-making tasks.

This paper describes baseline study design and results, with a focus on issues related to elicitation and assessment of team communications. Researchers predicted communication-based measures of information transfer, behavior, and encouragement would decline with fatigue.

Participants were predicted to not notice the predicaments of their teammates, be less responsive, and be slower to realize changes in their situation. This is consistent with predictions of performance under stress in general (Cannon-Bowers & Salas, 1998; Driskell & Johnston, 1998; Klein, 1996). Participants were also expected to be slower in action and less effective in sequencing activities as a result of their fatigue level.

METHOD

Participants

Participants were USAF officers awaiting Air Battle Management Training at Tyndall AFB, FL. Nine, three-person teams participated in this study (25.9% female, mean age = 26, s.d. = 3.2 years). Three teams were all male; six were mixed gender. All participants had previously attended the Aerospace Basics Course, which introduced them to basic principles of USAF C2 concepts.

Design and Procedure

The overall approach of this study was to (a) develop C2 scenarios that elicited desired aspects of team performance, (b) develop an array of measures of team performance, (c) obtain research participants comparable to USAF C2 operators, (d) train participants to a high level of performance, and (e) have them perform scenarios overnight without stimulants, after having been awake and performing all day.

The C2 environment offers an appealing opportunity for researchers. C2 operators work with computer screens and computer-mediated communications, an environment that can be well replicated. Scenarios were carefully constructed to ensure they were operationally relevant,

elicited the performance of interest and enabled good measures. Investigations of sustained operations pose great challenges, because scenarios cannot be replicates or strong practice effects will occur (Elliott, Coovert, Barnes, & Miller, 2003). Therefore, multiple scenarios equivalent in task difficulty were necessary.

Scenarios were created for a PC-based team task environment (Airborne Warning and Control System (AWACS) Agent-Enabled Decision Group Environment (AEDGE™)) that was developed for investigations of C2 team performance. AWACS AEDGE™ is a federation of intelligent agent-based functions that enables C2 scenario construction with multiple roles and entities (Hicks, Stoyen, & Zhu, 2001; Petrov & Stoyen, 2000). Intelligent agent technology enables decision support to each role and utilization of synthetic computer-driven role players.

Scenarios were designed to reflect USAF C2 tactical operations and meet criteria for controlled naturalistic research, as discussed by Brehmer and Dorner (1993) and Bowers, Salas, Prince, and Brannick (1992). Scenarios required coordinated action, decision-making, and adaptive response to time-critical situations. Time-critical retargeting was chosen as the operational theme of all scenarios. A prototype scenario was constructed, with designated targets and decoys that appeared throughout the scenario. Friendly assets (e.g., unmanned aerial vehicle (UAV) assets, bomber, jammer, and fighter aircraft) were assigned friendly roles played by participants. Enemy assets included surface-to-air missile (SAM) sites and fighter aircraft that varied in threat level. Additional enemy assets appeared at intervals, in the form of "popup" SAM sites and additional fighter aircraft.

When assets were distributed across participants, there was a high need for coordinated action. Participants in these scenarios had to identify and verify SAM targets and coordinate their resources to form "strike" packages. Enemy SAM sites needed to be jammed so that friendly

bombers and fighters would not be shot down and friendly bombers had to be protected by friendly fighter aircraft.

For all scenarios, the primary mission was always the same: find and destroy hostile targets. Twenty targets were presented throughout each scenario, with half of these being decoys. All targets were placed the same distance from friendly weapon assets and all appeared in similar task tempos. In each scenario, all friendly roles began with the same type and number of assets and were presented with additional assets equivalent in type and timing across scenarios. Thus, for every five-minute increment, participants owned the same number of assets and faced the same number of hostile targets, except for any losses in targets and assets that were a function of their own performance.

Once the prototype scenario was developed, alternates were constructed based on the same underlying structure. In each scenario, similar assets were assigned at similar times, creating similar events. To minimize recognition of this underlying structure, surface characteristics of scenarios were changed, such as geography and political context.

Measures

An array of measures of AEDGE™ performance were taken. These included observer-based assessments, many indices taken from AEDGE™ output, and capture/coding of communications. Only measures included in the analyses will be described here.

Raw measures of mission outcome and team process were captured and time-stamped by simulation. Mission outcome scores were represented by the type, number, and relative value of assets that were lost by "friendly" and "hostile" roles. Each asset was given a relative score value, generated by a weapons director expert, and validated by other weapons directors. For

these participants, the overall mission outcome score was based on the point value obtained after subtracting all friendly losses from all hostile losses.

Coding is a laborious and time-consuming process. There are several approaches to choose from: event-based analyses (e.g., communication related to particular events), analyses for certain dynamics (e.g., identification of indications of double loop learning), or coding schemes that classify individual utterances. For the initial foray in communication analyses, several existing schemes that relate communication dynamics to C2 performance (Artman & Granlund, 1998; Kanki & Foushee,1989; Hutchins, Hocevar, & Kemple, 1999; Colquitt, Hollenbeck, Ilgen, LePine, & Sheppard, 2002) and coding schemes that relate team processes and performance (Bales, 1950; Mulder & Swaak, 2000) were considered. After much review, researchers chose to digitally record and transcribe all communications (including communication during pre-mission planning, mission execution, and debriefing). In addition all email communications were captured, along with other communications such as requests for asset transfers.

The coding scheme used for this study, as illustrated in Figure 1, was crafted upon core aspects of communication that were common to several approaches. Each category was chosen through consideration of (a) relevance to team decision-making, team coordination, and fatigue and (b) distinctiveness of category. Specifically, the researchers wanted to capture efficiency of communication, encouragement, expressions of fatigue and aspects of information exchange as they related to the identification of threats and coordination of action. This coding scheme was chosen partially for its usefulness in analyses relating to decision-making.

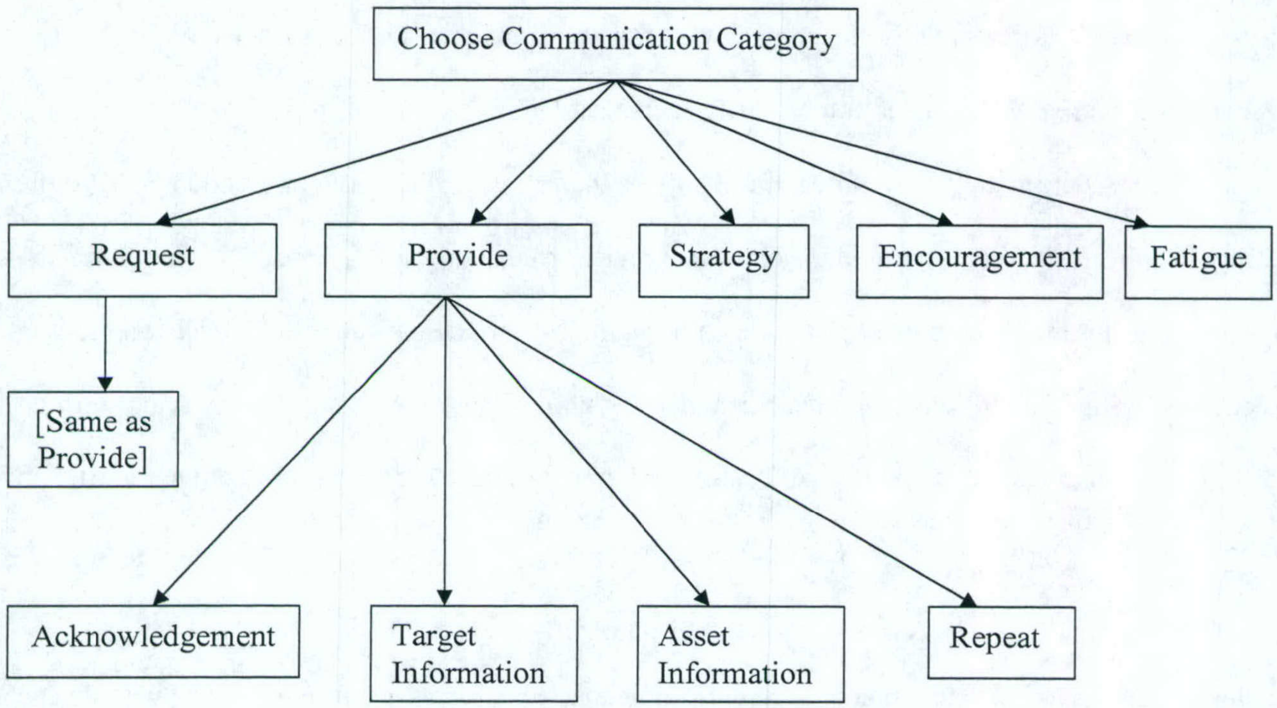
The breakdown of provide versus request information, along with other categories (e.g. acknowledgement of information and encouragement) have been consistently used as indicators

of leadership and communication effectiveness (Bales, 1950). This scheme allows one to assess total counts of different types of communication, in terms of information transfer, coordination of activities, acknowledgements, encouragements, and expressions of fatigue.

Each utterance was coded according to who provided it and whether the utterance requested information, requested acknowledgement of a prior comment, or requested a repeat of communication OR provided information, provided acknowledgement of a prior comment, or provided a repeat of communication. If the utterance requested or provided information, it was further categorized as to whether it was referring to a particular target (e.g., threat level, location) or a particular friendly asset (e.g., location, type). Then utterances were further coded according to whether the utterance: 1) concerned strategy, 2) was encouragement, or 3) expressed fatigue. All utterances were also coded as to whether or not they were task-related.

Explicit definitions and examples were provided for each category. Researchers used this initial scheme to code the same set of utterances. They then compared results, discussed discrepancies, and refined definitions. This was repeated until high agreement was achieved (95% or above). Once high agreement was established, additional coders were trained using the refined category distinctions and examples. Examination of their ratings also yielded high agreement (95% or above).

Figure 1: Communication coding scheme.



Procedure

Each participant completed 40 hours of training sessions during a one-week period. Participants were trained on C2 assets, capabilities, and tactics (10 hours) and AEDGE™ interface functions (30 hours). Participants were trained in three distinct C2 functional roles: intelligence, surveillance, and reconnaissance (ISR), SWEEP, and STRIKE. ISR owned assets such as UAV, STRIKE owned assets such as air-to-ground bombers and airborne jammers, and SWEEP owned assets such as air-to-air fighter aircraft.

Training consisted of a description and discussion of roles and tactics, software interface instruction, and hands-on training. These practice sessions began with interface functionality, then simple scenarios where each participant had all assets (thus lowering the need for coordinated action). These sessions were followed by scenarios with more specialized,

interdependent roles that progressed in complexity and were comparable to experimental sessions. Each participant's performance was closely monitored and guided by an instructor. Participants were debriefed and tutored after each scenario.

The experimental session began at 1800 on the last day of training and ended at 1100 the following morning. Each participant chose a specific role, which was constant throughout the session. During the session, they participated in eight, 40-minute team-based C2 decision making scenarios, with 20 additional minutes for mission planning and debriefing. At intervals through the experimental sessions, participants provided oral temperatures and subjective reports on mood and sleepiness.

RESULTS

Analysis of mission outcome scores indicated that teams performed least well during Session 6, improving somewhat for Sessions 7 and 8. This may be due to circadian rhythm cycles as opposed to fatigue. Because this trend was evident after the second team, researchers decided to code and analyze the communications of the first and sixth sessions for this investigation. This paper is based on data from nine teams. Given this low sample size, an alpha level of .10 was used for all analyses. Table 1 provides descriptives and paired-sample t test results for each variable.

Researchers expected that task-related communication and encouragement would decrease and references to fatigue would increase. All variables in Table 1 differed in the expected direction, with the exception of information requests about targets. Not all differences were statistically significant (this may be due to low statistical power from the low N). Researchers speculate that participants maintained communication regarding targets even when tired, because this information was essential to performance.

Despite the low sample size and statistical power, the majority of the comparisons, as illustrated in Figure 2, approached or were statistically significant. Expressions of fatigue increased, as expected ($p=.002$). Participants reported they felt sleepier (means of 1.93 and 4.85) and were not allowed to use caffeine, therefore it is assumed the experimental manipulation did succeed at fatiguing them.

Several aspects of task-related communication differed significantly. As illustrated in Figure 2, the first variable represents the total number of communications regarding assets and strategy. Significant decreases occurred for this type of information ($p=.002$), comments related to strategy ($p=.001$), total communications ($p=.009$), and total task-related communications ($p=.003$). Expressions of encouragement declined (from a mean of 3.937 to 3.321, $p = 0.208$).

The trends shown in the data are further illustrated in Figure 3, which represents the difference between sessions for the total of all communications, total of all task-related communications, total of information regarding assets and strategy, total provides, total requests, and total target information. It is interesting that while task-related communication decreased significantly ($p=.003$), the total provides ($p=.049$), total requests ($p=.110$), and total target information (means of 28.778 and 27.222, $p=.680$) did not change as much. This further indicates that communications were focused on target information when participants were tired.

The mission outcome variables in Table 2 reflect outcomes based on assets remaining at the end of each mission: hostile assets killed by friendly assets (HKBF) and friendly assets killed by hostile assets (FKBH). Communication variables were examined for relation to these mission outcome variables. Paired t tests indicated statistical differences between means for both outcome variables. Hostiles killed by friendlies decreased significantly ($p=.005$), and friendlies killed by hostiles increased significantly ($p=.079$).

For Session 1, the two outcome variables had a correlation of -.689 (p=.040). As shown in Table 3, none of the correlations between the two outcome variables and the communication variables were significant in Session 1. With the range restriction evidenced by having a mode of 0 and a maximum of 2 for self-reports of fatigue, there was little fatigue in Session 1. A .581 correlation (p=.101) between level of fatigue and hostiles killed by friendlies was the correlation closest to significance.

For Session 6, the two outcome variables had a correlation of -.728 (p=.026). Table 4 shows that provide target information was the only communication variable that was significantly correlated with hostiles killed by friendlies for this session (p=.081). In contrast, five of the correlations between the communication variables and friendlies killed by hostiles were significantly negative. Provide and request variables that concerned target communications were significant. In addition, total communications, provide information, and encouragement were significant.

Variable	Session	M	N	SD	t	df	p
Total Communications	1	164.778	9	72.057	3.410	8	
	6	108.333	9	56.628			.009**
Total Task	1	160.333	9	68.642	4.102	8	
Communications	6	92.222	9	50.734			.003**
Provide Information	1	69.556	9	24.136	2.313	8	
	6	48.111	9	23.846			.049**
Provide Target	1	25.333	9	9.962	1.024	8	
Information	6	22.444	9	12.300			.336
Provide Asset	1	44.222	9	17.050	2.686	8	
Information	6	25.667	9	14.739			.028**
Request Information	1	20.556	9	11.359	1.799	8	
	6	13.778	9	10.183			.110
Request Target	1	3.444	9	2.068	-.924	8	
Information	6	4.778	9	5.740			.383
Request Asset	1	17.111	9	9.880	2.324	8	
Information	6	9.000	9	5.937			.049**

*$p < .10$. **$p < .05$.

Table 1. Descriptives and paired-sample t tests for communication variables by session. (table continues)

Variable	Session	M	N	SD	t	df	p
Strategy	1	70.222	9	37.439	5.043	8	
	6	30.333	9	18.934			.001**
Encouragement	1	4.000	9	3.937	1.368	8	
	6	2.556	9	3.321			.208
Fatigue	1	0.444	9	0.727	-4.523	8	
	6	13.556	9	8.748			.002**

$^{*}p < .10$. $^{**}p < .05$.

Table 1. (continued)

Figure 2: Number of communications related to (a) assets and strategy, (b) encouragement, (c) target information, and (d) expressions of fatigue, at Sessions 1 and 6.

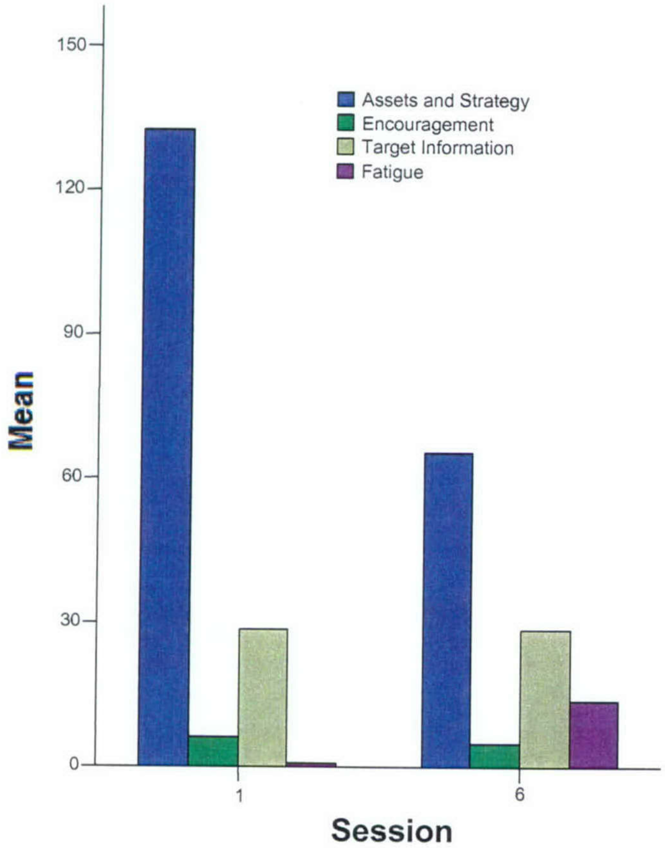
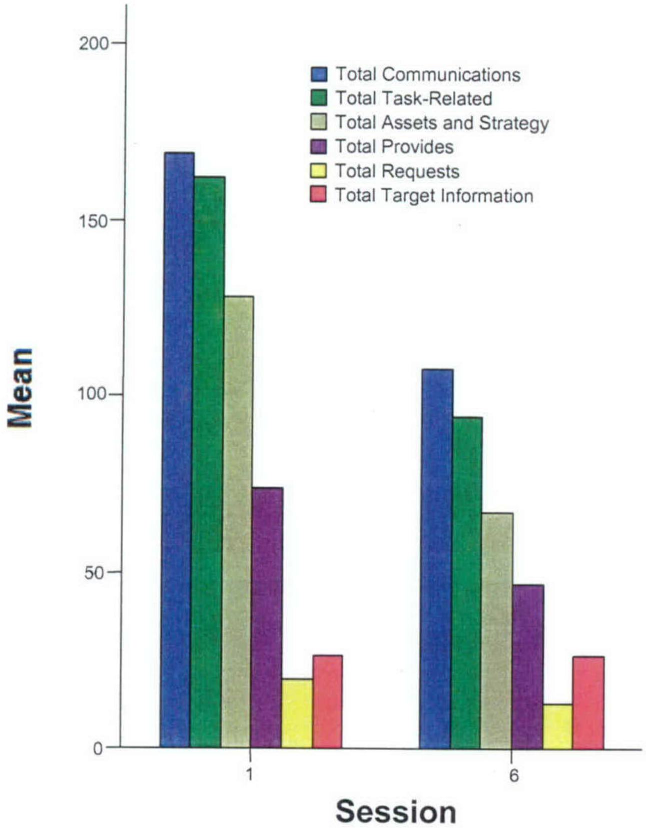


Figure 3: Total communications and task-related communications at Sessions 1 and 6.



Variable	Session	M	N	SD	t	df	p
HKBF	1	43.556	9	5.854	3.879	8	
	6	32.444	9	6.044			.005**
	Total	38.000	18	8.124			
FKBH	1	4.778	9	3.930	-2.016	8	
	6	8.222	9	4.684			.079*
	Total	6.500	18	4.554			

*$p < .10$. **$p < .05$.

Note. HKBF = hostile assets killed by friendly assets;
FKBH = friendly assets killed by hostile assets.

Table 2. Descriptives and paired-sample t tests for overall mean outcomes of hostile assets killed by friendly assets and friendly assets killed by hostile assets by session.

	HKBF	FHBH
Total Communications	.415	-.245
Total Task Communications	.405	-.247
Provide Information	.441	-.133
Provide Target Information	.236	-.078
Provide Asset Information	.486	-.143
Request Information	.322	-.207
Request Target Information	-.054	-.032
Request Asset Information	.381	-.231
Strategy	.361	-.305
Information on Assets and Strategy	.435	-.275
Encouragement	.418	-.129
Fatigue	.581	-.224

*p < .10. **p < .05.

Note. HKBF = hostile assets killed by friendly assets;
FKBH = friendly assets killed by hostile assets.

Table 3. Correlations between communication variables and outcome variables for session 1.

	HKBF	FKBH
Total Communications	.375	-.631*
Total Task Communications	.317	-.566
Provide Information	.465	-.634*
Provide Target Information	.611*	-.826**
Provide Asset Information	.243	-.336
Request Information	.111	-.429
Request Target Information	.230	-.644*
Request Asset Information	-.031	-.112
Strategy	.204	-.489
Information on Assets and Strategy	.194	-.398
Encouragement	.428	-.587*
Fatigue	.385	-.507

*$p < .10$. **$p < .05$.

Note. HKBF = hostile assets killed by friendly assets;
FKBH = friendly assets killed by hostile assets.

Table 4. Correlations between communication variables and outcome variables for session 6.

DISCUSSION

Implications outside the military arise from this paper. Long working hours causing signs of worker burnout are increasingly prevalent. It is becoming more common for employees to take less time off from work and to even feel guilty when they do so. Due in part to cell phones,

email, and remote access voice mail, workers are increasingly tethered to their work. American productivity is up, but so is the financial cost of coping with worker stress (Robinson, 2003).

This paper was based on nine teams (N=9), a low sum for degrees of freedom, yet examining nine teams took a huge amount of effort. The rigor of the method used should be emphasized, especially with regard to scenario development and training. The level of effort and attention to experimental control, enables present authors to argue that success was met in eliciting performance that was complex, naturalistic, and operationally relevant, while maintaining equivalence in workload, and minimizing practice effects.

The transcription and coding of communications were achieved through much systematic effort, with very high inter-rater reliability (over 95% after training). This speaks to the clarity of the communication coding scheme. In addition, the communication scheme allowed researchers to track information exchange that was both explicit (responses to requests for information) and implicit (provision without request). At the same time, the classification of content, with regard to decision cues versus communication, related more directly to teamwork (e.g., sequencing of activities). This communication appeared to be more affected by fatigue, which indicated a "tunneling in" effect.

It was evident that researchers did elicit participants' subjective experience of fatigue, based on communications, self-reports, and outcome measures. In addition, researchers found evidence of fatigue on participants' communication patterns and performance. Participants definitely communicated less when tired. However, they maintained communications about certain aspects of information, such as core critical information regarding hostile targets. Reductions in communication had to do with discussion of their assets and coordinating strategies, information that was not as critical to mission success. It is speculated that team

members maintained communication regarding targets even when tired because it was essential for performance, and simply reduced all other communications (except expressions of fatigue).

The reduction in communication regarding coordinating strategies and the assets of other team members, indicated possible detriments to team processes, particularly as mission outcomes were reduced. On the other hand, reduced communications, as indicated by higher levels of implicit coordination, have been associated with better performance in C2 situations (Elliott, Dalrymple, & Neville, 1997; Serfaty, Entin, & Volpe, 1993). When a team is providing task-related information without requests, it is an indication of implicit coordination, and this has been related to high performing teams (Serfaty & Entin, 1995; Serfaty, Entin, & Volpe, 1993). As teams in a study by Elliott, Dalrymple, & Neville (1997) became more practiced, they learned to provide critical information and execute coordinating strategies with less effort and explicit communication. If this were so in this study, the streamlined process may have reduced the effect of fatigue on performance. This would be consistent with findings and the argument that in some cases, stress can enhance performance (Klein, 1996).

Certainly, this is an area for further study. It has been argued and demonstrated that stress can be an effective context for training (Driskell & Johnston, 1998; Johnston & Cannon-Bowers, 1996). Perhaps in the same way, performance in fatiguing conditions can enhance or accelerate learning of team coordination. In this study, participants had in-depth training of coordinating strategies. This kind of training has been demonstrated effective for performance under stress (Serfaty, Entin, & Johnston, 1998).

Our current goal is to model and predict, to the extent possible, what kinds of error will occur, by whom, when, and why. An underlying goal is the identification and development of countermeasures to ameliorate the effects of fatigue. These will likely focus on training,

information visualization, decision aiding, and sleep/wake management. Potential research topics are numerous. We hope that this report communicates the operational relevance, methodological challenges, and implications of team performance research.

ACKNOWLEDGEMENTS

Many thanks to Mathieu Dalrymple and Phil Tessier of General Dynamics for all their work on this project, and to Christy Graham of General Dynamics for transcribing the audio.

REFERENCES

Artman, H, & Granlund, R. (1998). Team situation awareness using graphical or textual databases in dynamic decisionmaking. In T. R. G. Green, L. Bannon, C.P. Warren, & J. Buckley (Eds.), *Proceedings of ECCE-9, Ninth European Conference on Cognitive Ergonomics* (pp. 151-156).

Bales, R. F. (1950). *Interaction process analysis: A method for the study of small groups.* Reading, MA: Addison-Wesley.

Bonnet, M. H. (2000). Sleep deprivation. In M. Kryger, T. Roth, & W. Dement (Eds.), *Principles and practices of sleep medicine* (pp. 53-68). Philadelphia, PA: W.B. Saunders Company.

Brehmer, B., & Dorner, D. (1993). Experiments with computer-simulated microworlds: Escaping both the narrow straits of the laboratory and the deep blue sea of the field study. *Computers in Human Behavior, 9,* 171-184.

Bowers, C., Salas, E., Prince, C., & Brannick, M. (1992). Games people play: A method for investigating team coordination and performance. *Behavior Research Methods, Instruments, and Computers, 24*(4), 503-506.

Cannon-Bowers, J., & Salas, E. (1998). Individual and team decision making under stress: Theoretical underpinnings. In J. Cannon Bowers & E. Salas (Eds.), *Making decisions under stress: Implications for individual and team training*. Washington DC: APA Press.

Cohen, M. S. (1993). The naturalistic basis of decision biases. In G. Klein, J. Orasanu, R. Calderwood, & C. Zsambok (Eds.), *Decision making in action: Models and methods.* Norwood, NJ: Ablex Publishing Corporation.

Colquitt, J. A., Hollenbeck, J. R., Ilgen, D. R., LePine, J. A., & Sheppard, L. (2002). Computer-assisted communication and team decision-making accuracy: The moderating effect of openness to experience. *Journal of Applied Psychology, 87,* 402-410.

Driskell, J., & Johnston, J. (1998). Stress exposure training. In J. Cannon Bowers, & E. Salas (Eds.), *Making decisions under stress: Implications for individual and team training.* Washington DC: APA Press.

Eddy, D. R., & Hursh, S. R. (2000). *Fatigue avoidance scheduling tool*. Phase 1 SBIR Final Report, NTI Inc., Dayton OH, for the Air Force Research Laboratory, Contract F41624-99-C-6041.

Elliott, L., Coovert, M., Barnes, C., & Miller, J. (2003). Modeling performance in C2 sustained operations: A multi-level approach. *Proceedings of the 8th International Command and Control Research and Technology Symposium*. San Diego, CA. Published online: http://www.dodccrp.org/events/2003/8th_ICCRTS/pdf/023.pdf.

Elliott, L. R., Dalrymple, M. A., & Neville, K (1997). Assessing performance of AWACS command and control teams. *Proceedings of the Human Factors and Ergonomics Conference*. Albuquerque, NM.

Hicks, J., Stoyen, A., & Zhu, Q. (2001). Intelligent agent-based software architecture for combat performance under overwhelming information inflow and uncertainty. *Proceedings of the IEEE International Conference on Engineering of Complex Computer Systems* (pp. 200-210).

Hutchins, S., Hocevar, S., & Kemple, W. (1999). Analysis of team communications in "human-in-the-loop" experiments in joint command and control. *Proceedings of the 1999 Command and Control Research and Technology Symposium*. Published online: http://www.dodccrp.org/events/1999/1999CCRTS/pdf_files/track_1/101hutch.pdf.

Hursh, S. R. (1998). *Modeling sleep and performance within the integrated unit simulation system (IUSS)*. (Technical Report: Natick/TR-98/026L). United States Army Soldier Systems Command: Natick Research, Development and Engineering Center: Natick, Massachusetts.

Johnston, J., & Cannon-Bowers, J. (1996). Training for stress exposure. In J. Driskell & E. Salas (Eds.), *Stress and human performance*. Mahwah, NJ: Lawrence Erlbaum Associates.

Kanki, B, & Foushee, C. (1989). Communication as a group process mediator of aircrew performance. *Aviation, Space, and Environmental Medicine*, *60,* 402-410.

Klein, G. A. (1993). A recognition-primed decision (RPD) model of rapid decision making. In G. Klein, J. Orasanu, R. Calderwood, & C. Zsambok (Eds.), *Decision making in action: Models and methods*. Norwood, NJ: Ablex Publishing Corporation.

Klein, G. (1996). The effects of acute stressors on decision making. In J. Driskell & E. Salas (Eds.), *Stress and human performance.* Mahwah, NJ: Lawrence Erlbaum Associates.

Kryger, M., Roth, T., & Dement, W. (2000). *Principles and practices of sleep medicine* (3rd ed.). Philadelphia, PA: W. B. Saunders Company.

Mulder, & Swaak. (2000). How do globally dispersed teams communicate? Coding technology-mediated interaction processes (Report No. TI/RS/2000/040). Enshede Telematic Instituut.

Orasanu, J., & Salas, E. (1991). Team decision making in complex environments. In G. Klein, J. Orasanu, R. Calderwood, & C. Zsambok (Eds.), *Decision making in action: Models and methods.* Norwood, NJ: Ablex Publishing Corporation.

Petrov, P., & Stoyen, A. (2000). An intelligent-agent based decision support system for a complex command and control application. *Proceeding of the 6th IEEE International Conference on Engineering of Complex Computer Systems*. Tokyo, Japan.

Rasmussen, J. (1993). Deciding and doing: Decision making in natural contexts. In G. Klein, J. Orasanu, R. Calderwood, & C. Zsambok (Eds.), *Decision making in action: Models and methods.* Norwood, NJ: Ablex Publishing Corporation.

Robinson, J. (2003). *Work to Live: The Guide to Getting a Life.* New York: Berkley Publishing Group.

Serfaty, D., & Entin, E. E. (1995). Shared mental models and adaptive team coordination. *Proceedings of the International Symposium on Command and Control Research and Technology* (pp. 289-294). Washington, DC.

Serfaty, D., Entin, E. E., & Volpe, C (1993). Implicit coordination in command teams. *Proceedings of the 1993 Symposium on Command and Control Research* (pp. 53-57). Washington, DC.

Serfaty, D., Entin, E, & Johnston, J. (1998). Team Coordination Training. In J. Cannon Bowers, & E. Salas (Eds.), *Making decisions under stress: Implications for individual and team training*. Washington DC: APA Press.